1 Introduction

1.1 Project Overview and Objectives

The RETEC Group, Inc. (RETEC) and was contracted by the Wisconsin Department of Natural Resources (WDNR) in March 1998 to complete a Remedial Investigation (RI), Feasibility Study (FS), and Risk Assessment (RA) for chemically impacted sediments in the Lower Fox River and Green Bay. This project is being conducted under the direction of WDNR, with funding and technical assistance from the United States Environmental Protection Agency, Region 5 (EPA). On July 9, 1998, the EPA proposed adding the Lower Fox River and Lower Green Bay to the National Priority List (NPL) (Superfund). This project has been conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP).

The overall objective of this RI/FS/RA is to develop the necessary supporting information for the selection of a sediment remediation approach for the Lower Fox River and Green Bay that will be protective of human health and the environment. The Lower Fox River study area is defined as the 63 kilometer (km) (39 mile [mi]) portion of the river beginning at the outlet of Lake Winnebago and terminating at the mouth of the river into Green Bay (Figure 1-1). The study area also includes all of Green Bay, which is shown on Figure 1-2.

The RI report, prepared by RETEC and Natural Resource Technology, Inc. (NRT), describes the physical, chemical and biological characteristics of the Lower Fox River and Green Bay. The RA report has been prepared concurrently with this RI report and assesses the potential risks posed to human health and the environment from the compounds found in the Lower Fox River and Green Bay ecosystems. The FS report evaluates applicable remedial alternatives to support the selection of a remedy to eliminate, reduce, and/or control risks identified in the RA. This RI/FS report is consistent with the findings of the National Academy of Science's National Research Council Report entitled *A Risk Management for PCB Contaminated Sediments* (NRC, 2001).

The RI included the following activities:

- Compilation, review, and organization of existing data available for the Lower Fox River and Green Bay.

- Assessment of the quality and usability of the existing data.

- Collection of additional sample data in selected areas of the Lower Fox River during the summer of 1998.
- Description of the physical and ecological characteristics of the Lower Fox River and Green Bay along areas of sediment deposits.
- Evaluation of the occurrence, volume, and mass of chemical parameters of concern in sediment and water.

This RI report describes the magnitude and extent of chemicals of concern in sediments and water only. A substantial amount of chemical data have been collected from a variety of biological organisms. Biological impacts and their implications within the river system are addressed in the RA report.

1.2 Study Area Overview

General descriptions of the Lower Fox River and Green Bay are presented below to provide information about the physical setting of the RI study area and region.

1.2.1 Lower Fox River

The Lower Fox River flows northeast approximately 63 km (39 mi) from Lake Winnebago, the largest inland lake in Wisconsin, to Green Bay (Figure 1-1). The Fox River is the largest tributary to Green Bay, draining approximately 16,395 square kilometers (km^2) (6,330 square mi [mi^2]). The river has a mean discharge into Green Bay of approximately 122 cubic meters per second (m^3/s) (5,000 cubic feet per second [cfs]) (USGS, 1998c; Fitzgerald and Steuer, 1996). The change in river elevation between Lake Winnebago and Green Bay is approximately 51 meters (m) (168 ft) (National Oceanic and Atmospheric Administration [NOAA], 1992).

Historically, the Lower Fox River is impounded by 13 dams and 17 locks, which once made it navigable between Lake Winnebago and Green Bay. Currently, the Rapide Croche Lock is permanently closed to restrict sea lamprey migration and only the last two locks (at Little Rapids and De Pere) are open to recreational boats. The Lower Fox River is bounded upstream by two dams in the cities of Neenah and Menasha that control the pool elevation of Lake Winnebago and discharge to the river. The Neenah and Menasha channels connect Lake Winnebago with Little Lake Butte des Morts (LLBdM). LLBdM is a relatively shallow section of the Lower Fox River, approximately 1,070 m (3,500 ft) wide and extending approximately 4.8 km (3 mi) (Figure 1-3).

Between the outlet of LLBdM and the Little Rapids dam, the Lower Fox River is generally less than 300 m (1,000 ft) wide and the channel meanders more in this stretch of the river than in other downstream reaches (Figure 1-4). Sediment is typically deposited on the inside portion of a meander bend, while the outer part of the meander bend (the cut bank) usually is erosional due to increased stream flow velocities. Between the Little Rapids and De Pere dams the river is again relatively straight, although not as wide or as shallow as LLBdM (Figure 1-5).

From the De Pere dam to the mouth, the Lower Fox River is a large, channelized stream that is stabilized along much of this stretch with either riprap or concrete reinforcement (Figure 1-6). Navigation for ocean bound vessels extends upriver approximately 4.8 km (3 mi) from Green Bay to the Fort James Paper Company (formerly Fort Howard) turning basin via a navigation channel with a maintained water depth of about 7.3 m (24 ft). Flow in this section of the river is sometimes reversed by wind-driven increases in Green Bay water levels, commonly known as seiche events.

1.2.2 Green Bay

The Green Bay of Lake Michigan is a narrow, elongated bay, oriented in a north-northeast -south-southwest (NNE-SSW) direction (Figure 1-2). At the south end, the bay is a freshwater estuary, due to the shallow water depths, while the northern end is a deep-water lake. The bay lies on the northeast shore of Wisconsin and the southeast shores of Michigan's Upper Peninsula (UP). The bay is bounded by the city of Green Bay at the south end and by both Big Bay de Noc and Little Bay de Noc on the north end. Big Bay de Noc and Little Bay de Noc are separated by the UP's Stonington Peninsula (Sinclair, 1960). In Wisconsin, the bay is separated from Lake Michigan by the Door Peninsula while the UP's Garden Peninsula separates Big Bay de Noc from Lake Michigan (Figure 1-2). Green Bay is connected with the remainder of Lake Michigan on its northeast side along a line between Washington, Rock, St. Martin's, Poverty, and Summer Islands (Figure 1-2). Rock Island, which lies about 2.4 km (1.5 mi) north of Washington Island, marks the northern tip of Door County. The islands north of Rock Island lie within the state of Michigan.

Green Bay is approximately 190 km (119 mi) long and has an average width of 37 km (23 mi). The bay covers an area of approximately 4,150 km^2 (1,600 mi^2) and has a volume of about 83 cubic kilometers (km^3) (20 cubic miles [mi^3]). The mean depth of the bay is approximately 20 m (65 ft). The maximum depth reaches 54 m (176 ft) at a location about 6.4 km (4 mi) west of Washington Island (Bertrand, *et al.,* 1976).

The Green Bay watershed drains approximately 40,000 km^2 (15,625 mi^2) or about one-third of the Lake Michigan drainage basin. Two-thirds of the Green Bay drainage is in Wisconsin and one-third in Michigan's UP (Bertrand, *et al.,* 1976). Although there are a number of Green Bay tributaries, the United States Geological Survey (USGS) has measured discharge for 10 tributaries. The measured discharge for these tributaries, along with the drainage area for each, is summarized below. Except for the Lower Fox River, the discharge results listed below are for Water Years 1989 and 1990, which run from October 1, 1998 through September 30, 1990. Data from the Lower Fox River extends from 1898 through 1998.

The Fox River is by far the largest Green Bay tributary based on both discharge and drainage area. The Fox River contributes approximately 42 percent of the total drainage into Green Bay (Bertrand, *et al.,* 1976). Due to its volume, as well as the relatively higher concentration of industrial activity and pollutant load, the Fox River is the tributary of greatest interest with respect to sediment and water quality in Green Bay. Over 95 percent of the polychlorinated biphenyl (PCB) load and 70 percent of the suspended sediments flowing into the bay are derived from the Lower Fox River (WDNR, 1999a; Smith, *et al.,* 1988).

The Menominee River is the only other Green Bay tributary with a mean discharge over 56.6 m^3/sec (2,000 cfs) and a drainage area over 10,000 km^2 (3,861 mi^2). In addition to the ten tributaries that USGS measured, five other Green Bay tributaries have been utilized by LTI Environmental Engineering (LTI, 1999) to model PCB and solids loads into Green Bay. However, stream discharge data were not available for these five tributaries.

Summary of Green Bay Tributaries

Tributary	State	Drainage Area Km^2(mi^2)	Mean Discharge m^3/sec (cfs)
Fox	WI	16,394 (6,330)	149 (5,262)
Duck	WI	394 (152)	1.2 (42.6)
Suamico	WI	157 (60.7)	0.95 (33.4)
Pensaukee	WI	386 (149)	1.7 (59)
Oconto	WI	2,416 (933)	15.9 (560)
Peshtigo	WI	2,991 (1,155)	20 (704)
Menominee	WI/MI	10,748 (4,150)	78 (2,750)
Cedar	MI	917 (354)	N/A
Ford	MI	1,282 (495)	9.3 (327)
Escanaba	MI	2,383 (920)	23 (828)
Tacoosh	MI	75 (29)	N/A
Rapid	MI	352 (136)	N/A
Whitefish	MI	811 (313)	N/A
Sturgeon	MI	523 (202)	5.3 (188)
Fishdam	MI	243 (94)	N/A

Circulation within Green Bay is largely controlled by the prevailing southwesterly winds, which causes a large-scale generally counterclockwise circulation of the bay waters (Miller and Saylor, 1985; Smith, *et al.,* 1988). Localized currents are present throughout the bay and rotate both clockwise and counter-clockwise (HydroQual, 1999). The bay is also subject to seiches, defined as cyclical short-term oscillation of water levels caused by the earth's rotation, wind, and/or abrupt changes in barometric pressure. The seiches typically change water levels by several centimeters in the southern end of Green Bay, resulting in reversed flow in the Lower Fox River. Combined with storm conditions, seiche events have raised water levels at the mouth of the river by over one meter and the seiche effects can extend up to the De Pere dam, 11.3 km (7 mi) upstream from the mouth of the river. Seiche events result in the relatively rapid mixing of sediment-rich tributary waters, and therefore contaminant loads, with the water of Green Bay.

Discharge from the Lower Fox River into Green Bay is directed towards the east by the counterclockwise circulation pattern. Plumes of sediment-rich water can extend up to 20 km along the east shore of the bay (Smith, *et al.,* 1988). Sediment initially deposited in the southern end of the bay can become resuspended due to seiche events and be redeposited further up the east shore. Consequently, the majority of river-related sediment in Green Bay is present along the southern and eastern shores of the bay.

Larger urban areas located along the west shore of Green Bay include the cities of Green Bay, Marinette, Peshtigo, and Oconto, Wisconsin and Escanaba and Menominee, Michigan. The city of Sturgeon Bay, Wisconsin, is the largest urban area located on the east shore of Green Bay (Figure 1-2).

1.3 Study Area River Reaches and Bay Zones

In order to facilitate data presentation and discussion in the RI, the Lower Fox River and Green Bay have been divided into reaches and zones, respectively. These river reach and bay zone designations are used throughout the RI/FS/RA and are described below.

1.3.1 Lower Fox River Reaches

Based on previous investigations, the river has been divided into four reaches and, further, into specific sediment deposits or units within these reaches. Three of these reaches are located upstream of the De Pere dam and the fourth reach extends from the De Pere dam to the mouth of the river. Above the De Pere dam, there are 35 individual sediment deposits (WDNR, 1995). From the De Pere dam to the mouth of the river at Green Bay soft sediment is present over almost the entire river bottom and individual deposits were not established. Rather, the river bottom in this reach was separated into discrete sediment management units (SMUs). The reaches and associated sediment deposits/SMUs discussed in this RI report (as well as in the RA and FS reports) include the following:

- **Little Lake Butte des Morts (LLBdM) Reach** (Figure 1-3) - Extending from the outlet of Lake Winnebago to Appleton for a distance of approximately 10 km (6 mi), this reach includes sediment deposits A through H and POG.

- **Appleton to Little Rapids Reach** (Figure 1-4)- Extending from Appleton to the Little Rapids dam for a distance of approximately 32 km (20 mi), this reach includes deposits I through DD. Sediments in deposits N and O were dredged from the river as part of the sediment remediation demonstration project in the fall of 1998 and the summer through fall of 1999.

- **Little Rapids to De Pere Reach** (Figure 1-5) - Extending from the Little Rapids dam to the De Pere dam for a distance of approximately 9.7 km (6 mi), this reach includes sediment deposits EE through HH. These deposits form a nearly continuous layer of soft sediment that extends for approximately 8.5 km (5 mi) upstream of the De Pere dam.

- **De Pere to Green Bay Reach** (Figure 1-6) - This reach extends about 11.3 km (7 mi) from the De Pere dam to the mouth of the Fox River. Due to the presence of a large and continuous layer of soft sediment between the dam and the river mouth, this area has been divided into 96 SMUs (numbered 20 through 115) and 16 water column segments (6 SMUs to a segment). The SMUs and water column segments were initially established for computer modeling studies. This reach is also referred to as Green Bay Zone 1 for certain modeling activities.

1.3.2 Green Bay

1.3.2.1 Green Bay Zones

Green Bay has been subdivided into four zones by previous investigators (EPA, 1989). Green Bay zones 2, 3, and 4 are shown on Figure 1-2.

- **Zone 1** is identical to, and will be referred to hereinafter as, the De Pere to Green Bay Reach of the Lower Fox River, as discussed above.

- **Zone 2** (Figure 1-2) extends from the river mouth to a line perpendicular with the long axis of the bay (trending northwest-southeast (NW-SE)) about 12.2 km (7.6 mi) from the river mouth. This line crosses the bay near Little Tail Point on the west side of the bay (659,977.31E & 447,330.59N, Wisconsin Trans-Mercator Projection, 1927 [WTM 27]) and near Red Banks/Point Vincent on the east side of the bay (668,804.12E & 441,069.64N, WTM 27) (Velleux, 2000). This is approximately 10 km (6.2 mi) south of Dyckesville, Wisconsin.

- **Zone 3** (Figure 1-2) extends from the east-west line marking the northern boundary of Zone 2 to a line just below Chambers Island. The northern boundary of Zone 3 is located about 87 km (54 mi) north of the mouth of the Fox River. Therefore, Zone 3 extends for a distance of approximately 75 km (47 mi). The boundary line of Zone 3 connects Beattie Point, in the Michigan UP (695,979.10E & 511,652.33N WTM 27) to Fish Creek, Wisconsin (715,892.56E & 500,356.72N WTM 27) on the Door Peninsula (Velleux, 2000).

- **Zone 4** (Figure 1-2) includes the remainder of Green Bay north of Chambers Island, including both Big Bay de Noc and Little Bay de Noc. From the south side of Chambers Island to the northern shores of Big Bay de Noc, the distance is approximately 102 km (63 mi).

Green Bay zones 2 and 3 are further divided into “east” and “west” segments by a line trending northeast-southwest (NE-SW) from the Fox River to Chambers Island. Zones 2A and 3A are located on the west side of this line while zones 2B and 3B are located on the east side of this line (Figure 1-2).

1.3.2.2 Inner and Outer Bays

Green Bay is also divided into the “inner”and “outer” bay and Chambers Island generally serves as the line of demarcation between these two areas. For the purposes of this RI/FS the "inner bay" includes Green Bay zones 2 and 3 and the "outer bay" is Zone 4, although there may be other uses of these terms in other literature and studies. The inner and outer bay designations are based on the physical environment of Green Bay, since water depths of the inner bay are much shallower than depths of the outer bay. Also, due to these depths, the water temperatures and the commercial and sport fisheries of the inner and outer bay are different.

1.3.2.3 Lower Green Bay

Previous researchers, as well as the efforts described herein, indicate that the majority of the PCB impacted sediments occur within the inner bay and the highest concentrations of PCBs are located in Zone 2, south of Long Tail Point and Point Au Sable. Use of the term “lower Green Bay” refers to this portion of Zone 2, located between the mouth of the Lower Fox River and these two points.

1.4 Background

The following information describes the development of the river and bay region as well as historical conditions and resources. This section also describes how historical development and practices have impacted the river and bay regions.

1.4.1 Site History

Green Bay and the Lower Fox River have long been important transportation corridors within the state of Wisconsin. Abundant and reliable food supplies, as well as other natural resources in the area, fostered development prior to arrival of Europeans to the region. French explorers arrived in the region in 1634 when Jean Nicolet landed on the eastern shore of Green Bay at Red Banks (Burridge, 1997). Following this, the French began colonizing the area, focusing on its vast wealth of furs and game, and exploring for routes further west. In addition to naming Green Bay, the French also referred to the bay as “La Baye de Puans” or the “Stinking Bay” (Burridge, 1997). This name reflected the observations of the

French explorers, likely indicating that lower Green Bay was a characteristically eutrophic water body.

French dominance in the area declined after 1731, as British and Canadian influence in the area increased. British and Canadian interests were dominant in the area until the end of the War of 1812, when the area became a territory of the United States (Burridge, 1997). During the 1820s and 1830s, Green Bay was a key entrance into the American west and large scale migration to the area and development occurred (Burridge, 1997).

An important factor in development of the area was the presence of the Fox and Wisconsin Rivers. Early residents proposed connecting Green Bay and the Mississippi River via the Fox and Wisconsin Rivers. In 1839-40, representatives of the U.S. federal government (the Topographical Engineers office) recommended the construction of a series of dams, locks, canals, and other modifications in order to make the Lower Fox River navigable between Green Bay and Lake Winnebago (Burridge, 1997). Channelization of the Lower Fox River began as part of this effort, as did construction of the locks and dams at each of the river's rapids. Following many unsuccessful attempts to complete a viable water-way connecting Green Bay with the Mississippi River, the federal government, through the United States Army Corps of Engineers (USACE), assumed authority for maintaining the Lower Fox River and Green Bay navigation channel and system. With this, came the responsibility for maintaining the Lower Fox River dams, locks, and canals. The structures the USACE took control of in 1872 are listed below. The USACE is still listed as owner of eight dams on the Lower Fox River (Table 3-8).

Lower Fox River Dam, Lock, and Canal Summary - 1872 (Burridge, 1997)

Dam	Canal length	Elevation Drop	Power Generation (horsepower)
Menasha Dam	1,317 m (4,320 ft)	2.5 m (8.2 ft)	2,487
Appleton Upper Dam	1.9 km (1.2 mi)	4.3 m (14 ft)	4,238
Appleton Middle Dam		4.3 m (14 ft)	2,225
Appleton Lower Dam		2.6 m (8.5 ft)	2,558
Cedars Dam (at Kimberly)	no listing	no listing	no listing
Little Chute Dam	1,980 m (6,500 ft)	11 m (36.2 ft)	no listing
Combined Locks Dam	no listing	6.6 m (21.8 ft)	no listing
Grand Kaukauna Dam	2,255 m (7,400 ft)	15.3 m (50.3 ft)	no listing
Rapide Croche Dam	536 m (1,760 ft)	2.6 m (8.6 ft)	no listing
Little Rapids Dam	290 m (950 ft)	2.1 m (7 ft)	no listing
De Pere Dam & Lock	no listing	2.7 m (9 ft)	no listing

Development of the Lower Fox River and Green Bay area increased with development of the river and bay navigation channel and system. Along with development came utilization, exploitation, and degradation of the local resources, including the water quality of the river and bay.

Water quality degradation in the Lower Fox River and Green Bay occurred over an extended period of time, largely beginning in the mid-1800s and continuing through the mid-1900s. As the population of the Green Bay area increased during the early to mid-1800s, the fish and water of Green Bay, along with the timber and land of the region faced increased pressure from exploitation of the local resources (Smith, *et al.,* 1988). During the latter half of the 1800s, the regional forests were cut to supply the sawmills of the Lower Fox River and the lumber markets in the lower Midwest. The previously forested land was converted to agriculture and runoff from the surrounding farmlands and deforested areas added significantly to the nutrient and sediment loads of the Lower Fox River and Green Bay (Smith, *et al.,* 1988).

In addition to these nutrient and sediment loads, the introduction of untreated municipal sewage and industrial wastes also significantly contributed to decline of the Lower Fox River and Green Bay water quality. Both the sawmills and paper mills discharged sawdust and other fibrous material as well as waste sulfite liquors (chemical residues of the pulping operations) into the Lower Fox River. The sawdust and fibrous material formed large mats that floated on the water surface. In Green Bay, these mats reportedly covered several square kilometers of the water surface (Smith, *et al.,* 1988). The waste sulfite liquors and other industrial and municipal waste discharges spurred bacterial growth and algal blooms, severely lowering the dissolved oxygen (DO) levels in the river and bay. This resulted in widespread fish die-offs in the 1920s and 1930s. Low oxygen conditions extended into Green Bay as far as 30 km (19 mi) north of the mouth of the Fox River.

During the late 1800s, the commercial fishing industry had been established in the Green Bay area. However, due to pollution, over fishing, and the introduction of exotic species in Green Bay, several of the bay's most prized fishes disappeared. These included lake sturgeon, herring, and lake trout.

In 1938-39, a Pollution Survey of Green Bay and the Lower Fox River (De Pere to Green Bay Reach) was completed by the Wisconsin State Board of Health -Committee on Water Pollution and the Green Bay Metropolitan Sewerage District (GBMSD). The pollution survey was conducted to investigate the fish die-offs reported by local fishermen in Green Bay and other nuisance concerns.

A similar survey of the Lower Fox River in 1925-26 had found that "intolerable conditions existed for aquatic life during the critical summer months from below Wrightstown to Green Bay" (Wisconsin State Board of Health, 1939). Conclusions of the 1938-39 Pollution Survey (Wisconsin State Board of Health, 1939) included the following:

- Waste sulfite liquors were determined to be the major source of pollution in Green Bay during the winter months, and oxygen depletion occurs along the east side of Green Bay, reflecting the counterclockwise currents of the bay.

- Typical ice coverage in the bay would likely result in oxygen-depleted conditions, especially along the east side of the bay, and near the reported fish die-offs.

- The DO levels at De Pere, the Mason Street bridge in the city of Green Bay, and the mouth of the river were so low that the water could not support fish life during periods of warm temperature and low stream flows (during August and September).

- Although sewage treatment plants had removed large quantities of solids and scum from the river and lowered the bacterial load, the oxygen demand did not decrease significantly because it was calculated that 88 percent of the oxygen demanding materials were associated with the waste sulfite liquors.

The degraded conditions of the Lower Fox River and Green Bay continued into the 1940s and 1950s. Due to high levels of fecal coliform bacteria, resulting from the discharge of untreated municipal sewage, Green Bay's public beach was permanently closed to swimming in 1943. Due to a declining water table and groundwater supplies, as well as the pollution of the Lower Fox River and Green Bay, the city of Green Bay built a water supply pipeline in 1955 to bring Lake Michigan water to the city. The water supply line extends approximately 48 km (30 mi) from Green Bay to Kewaunee and it draws Lake Michigan water through an intake located about 6.4 km (4 mi) offshore.

Yellow perch populations, which had been the mainstay of the local commercial fishing industry, declined significantly during this time period. In 1943, approximately 1.08 million kilograms (kg) (2.4 million pounds) of yellow perch were caught; by 1966 the catch had declined to 73,480 kg (162,000 pounds), a decrease of more than 90 percent (Smith, *et al.*,1988). Further, in 1976, WDNR instituted fish consumption advisories and restricted commercial harvesting due to the presence of PCBs in the fish of the Lower Fox River and Green Bay. Due to the continued presence of PCBs in fish, the WDNR has restricted the commercial yellow perch catch in Green Bay to 90,720 kg (200,000 pounds) annually. The fish consumption advisories, as well as the introduction and migration of exotic species into Green Bay, continue to disrupt and severely limit commercial fishing.

Besides the decline in the commercial fishing catch, the populations of many piscivorous (fish-eating) birds also declined in the 1960s. Bird populations suffered from the eggshell-thinning effects of chlorinated pesticides, such as p.p'-dichlorodiphenyltrichloroethane (DDT) and dieldrin and EPA moved to ban these two pesticides in the early 1970s. The effects associated with chlorinated pesticides lead to concerns about other chlorinated compounds, including PCB, pentachlorophenol (PCP) and dioxins/furans. PCB, DDT and dieldrin were all detected in piscivorous birds in 1987 and 1988, years after the use and discharge of these compounds had been discontinued (Dale and Stromberg, 1993).

1.4.2 Historical PCB Use and Discharges

Based on the historical discharges to the river and bay, numerous compounds can be detected in the sediments and water as well as the aquatic and wildlife species within or frequenting the river and bay. During the early 1980s, more than 100 potentially toxic substances were found in Lower Fox River sediments, water, and fish tissue (Sullivan and Delfino, 1982). Recently, the list of parameters in the river and lower Green Bay have been estimated to include over 360 potentially toxic substances (IJC, 1992), including PCB, mercury, polynuclear aromatic hydrocarbons (PAHs) and ammonia. Other contaminants found in some, but not all deposits/SMU groups include the pesticides DDT, p.p'-dichlorodiphenyldichloroethylene (DDE), and p.p'-dichlorodiphenyl-dichloroethane (DDD), and PCP. Of the potentially toxic substances found, the Baseline Human Health and Ecological Risk Assessment report (RETEC, 2002) concluded that PCBs are the primary chemicals of concern.

During the 1950s, 60s, and 70s, many industries throughout the United States used and/or produced products that contained PCB. PCBs include a class of 209 related chlorinated organic compounds that share similar chemical properties and structure. PCB use was widespread because these compounds are chemically very stable, have a high heat capacity, and do not easily degrade in water. PCBs were historically used in electrical equipment, hydraulic fluids, fire retardants, cutting oil, and a number of other commercial and industrial processes (Merck, 1989).

In the early 1950s, National Cash Register (NCR) developed carbonless copy paper for office and business use. When struck by a typewriter or pressed with a pen, a coating of PCB emulsion on the paper released oils to produce the document copy. In 1954, local paper mills in the Lower Fox River valley began manufacturing carbonless copy paper and PCBs were released to the environment through process waste waters and through the de-inking and recycling of waste carbonless copy paper. Due to rising health concerns about PCBs released to the environment, use of PCBs in the production of carbonless copy paper ceased in 1971. However, recycling of the carbonless copy paper may have continued for a short time thereafter. Monsanto, the primary manufacturer of PCBs in the United States, ceased distribution of PCBs for applications which were uncontained and open to the environment in 1977.

The companies/entities involved in the manufacturing and recycling of carbonless copy papers have been identified as the potentially responsible parties (PRPs) pursuant to CERCLA. These companies formed the Fox River Group (FRG), which collectively have undertaken studies evaluating PCB impacts to the river and bay system. The FRG includes the following seven companies (listed alphabetically): Appleton Papers, Inc.; Fort James Corporation; NCR Corporation; P.H. Glatfelter Company; Riverside Paper Corporation; U.S. Paper Mills Corporation; and Wisconsin Tissue Mills, Inc.

WDNR completed an evaluation of PCB discharges to the Lower Fox River beginning in the 1950s and coinciding with the production and recycling of carbonless copy paper. WDNR (1999a) estimated that approximately 313,600 kg (691,370 pounds) of PCBs were released to the environment during this time, although the discharge estimates range from 126,450 kg to 399,450 kg (278,775 pounds to 880,640 pounds), based on the percentages of PCBs lost during production or recycling of carbonless copy paper. WDNR (1999a) estimated that 98 percent of the total PCB released into the Lower Fox River had occurred by the end of 1971. Further, WDNR (1999a) indicated that five facilities, including the Appleton Papers-Coating Mill, P.H. Glatfelter Company and associated Arrowhead Landfill, Fort James-Green Bay West Mill (formerly Fort Howard), Wisconsin Tissue, and Appleton Papers-Locks Mill, contributed over 99 percent of the total PCBs discharged to the river.

Currently, PCBs are discharged into Green Bay at the mouth of the Lower Fox River through sediment transport and PCB dissolution in the water column. Sediments are the most significant source of PCBs entering the water column (Fitzgerald and Steuer, 1996), and over 95 percent of the PCB load into Green Bay is derived from the Lower Fox River (WDNR, 1999a). Based on the data analyzed as part of this effort, approximately 70,000 kg (154,300 pounds) of PCBs have already escaped from the Lower Fox River into Green Bay.

1.4.3 Regulatory Response

1.4.3.1 Clean Water Act

In response to growing public concern about widespread and serious water pollution, Congress passed the Clean Water Act (CWA) in 1972. The CWA was the first comprehensive national clean water legislation and is the primary federal law protecting our nation's lakes and rivers. The CWA objectives were two-fold: 1) eliminate discharge of pollutants in the water; and 2) achieve water quality levels that support recreational activities, namely fishing and swimming. The objectives were met by allowing the states to set specific water quality criteria, require surface water discharge performance standards and to develop pollution control programs to meet these criteria.

1.4.3.2 Wisconsin Pollution Discharge Elimination System

The implementation of the Wisconsin Pollution Discharge Elimination System (WPDES) program in the mid-1970s greatly reduced the pollutant load to the Lower Fox River. However, low levels of PCBs were still detected in industrial and municipal wastewater discharges associated with the paper mills into 1990, due to the persistence and ubiquitous occurrence of these compounds in the environment (WDNR, 1999a). One of the largest pollutant loads identified within the area of concern (AOC), besides municipal and industrial discharge outfalls, was in-place sediments, especially with respect to PCBs.

1.4.3.3 Great Lakes Areas of Concern

Coinciding with passage of the CWA, the Great Lakes Water Quality Agreement (GLWQA) was signed by the United States and Canada in 1972 and amended in 1978 and 1987. The GLWQA established specific goals and remedial objectives for improving water quality within the Great Lakes Basin. Forty-three AOCs were identified for further assessment and management of Great Lakes water quality. The lower Green Bay and Lower Fox River were designated as an AOC. This AOC includes the Lower Fox River from the De Pere dam to the river mouth (11.3 km [7 mi]) as well as the southern portion of Green Bay.

The lower Green Bay Remedial Action Plan (RAP) (WDNR, 1988) established goals, objectives, and a community frame-work for implementing remedial actions for the lower Green Bay and Fox River AOC. The RAP effort was led by the WDNR with a Citizens Advisory Committee and Technical Advisory Committee, both comprised of representatives of the public and private sectors. Sixteen key actions and 120 associated recommendations were identified to restore the beneficial uses of system. High priority actions included the following:

- Reducing phosphorous and sediment loads to the bay
- Eliminating the toxicity of industrial and municipal discharges and the impacts of contaminated sediment
- Continuing efforts to restore the river's oxygen levels to improve fish habitat

WDNR, the EPA, and U.S. Fish and Wildlife Service (USFWS) have conducted evaluations of PCB contamination in sediment, fish, and wildlife in the Lower Fox River and Green Bay. Due to bio-accumulation of PCBs in fish and fish-eating predators, the WDNR issued the first fish consumption advisory for the area in 1976, while the state of Michigan issued the first Green Bay fish advisory in 1977. Eliminating sediments as a source of PCBs was one of the high priority items established by the RAP. Other significant sources of lake and river water quality degradation include deposition of airborne pollutants, such as PCBs, metals, and PAHs, and polluted runoff, which contributed total suspended solids (TSS) which increase eutrophic conditions within the inner bay (WDNR, 1988).

In addition to the lower Green Bay and Fox River AOC, the Menominee River AOC is located in Green Bay along the shores of the cities of Marinette, Wisconsin and Menominee, Michigan. The Menominee AOC includes the lower 4.8 km (3 mi) of the river from the Upper Scott Paper Company dam (Wisconsin) to the river's mouth and approximately 5 km (3 mi) north and south of the mouth along the adjacent shore of Green Bay. The primary cause of the identified use impairments is arsenic contamination in the turning basin and in sediments along the right bank of the river below the location of the chemical company in Marinette, Wisconsin. Other pollutants, such as mercury, PCBs, and oil and grease have also contributed to use impairments. Although PCBs are present in this AOC, the contribution of PCBs to Green Bay from the Menominee River is far less than from the Lower Fox River. Therefore, the Menominee River AOC is not addressed further in this RI report.

1.5 Application of NRC Findings and Recommendations

Based on national and growing concern regarding the long-term management of PCB-contaminated sediments, the National Academy of Sciences (NAS) was mandated by the United States Congress, via the National Research Council (NRC), to address the complexities and risks associated with managing

PCB-contaminated sediments. The NRC was tasked with reviewing the availability, effectiveness, cost, and effects of technologies used for the remediation of sediments containing PCBs. The results of their findings were published in a document titled *A Risk Management Strategy for PCB-contaminated Sediments* (NRC, 2001). Based on their review of PCB effects at several sites nationally, the NRC also concluded that PCBs in sediment pose a chronic risk to human health and the environment, and that these risks must be managed. The NRC developed a list of recommendations that captured a need for remedies that should be site-specific and risk-based, and that no one remedy (dredging, capping, or monitored natural recovery) is applicable or preferred for all sites.

The recommendations of the NRC were adapted by the EPA in a document titled, *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (EPA, 2002). EPA used the guiding principals defined by the NRC to develop a set of 11 risk management principles for application at CERCLA or RCRA sediment sites. The EPA guidance principles specify use of scientific, risk-based, site-specific remedy decisions using an iterative decision process, as appropriate, which evaluates the short-term and long-term risks of all potential cleanup alternatives. These principles are also consistent with the nine remedy selection criteria defined in the National Contingency Plan (NCP) (40 CFR Part 300.430) and application of these principles does not affect existing statutory and regulatory requirements. A comparison of the NRC-developed and the EPA sediment management principals is given in the white paper titled, *Applicability of the NRC Recommendations and EPA's 11 Management Principles*, which is included in the Responsiveness Summary.

The Lower Fox River and Green Bay RI/FS followed the guidance set forth by both the EPA and the NRC. These included:

- Structuring the documents so that a range of site-specific risks to human health and the environment were delineated, and articulating Remedial Action Objectives (RAOs) around which to structure potential remedial alternatives.

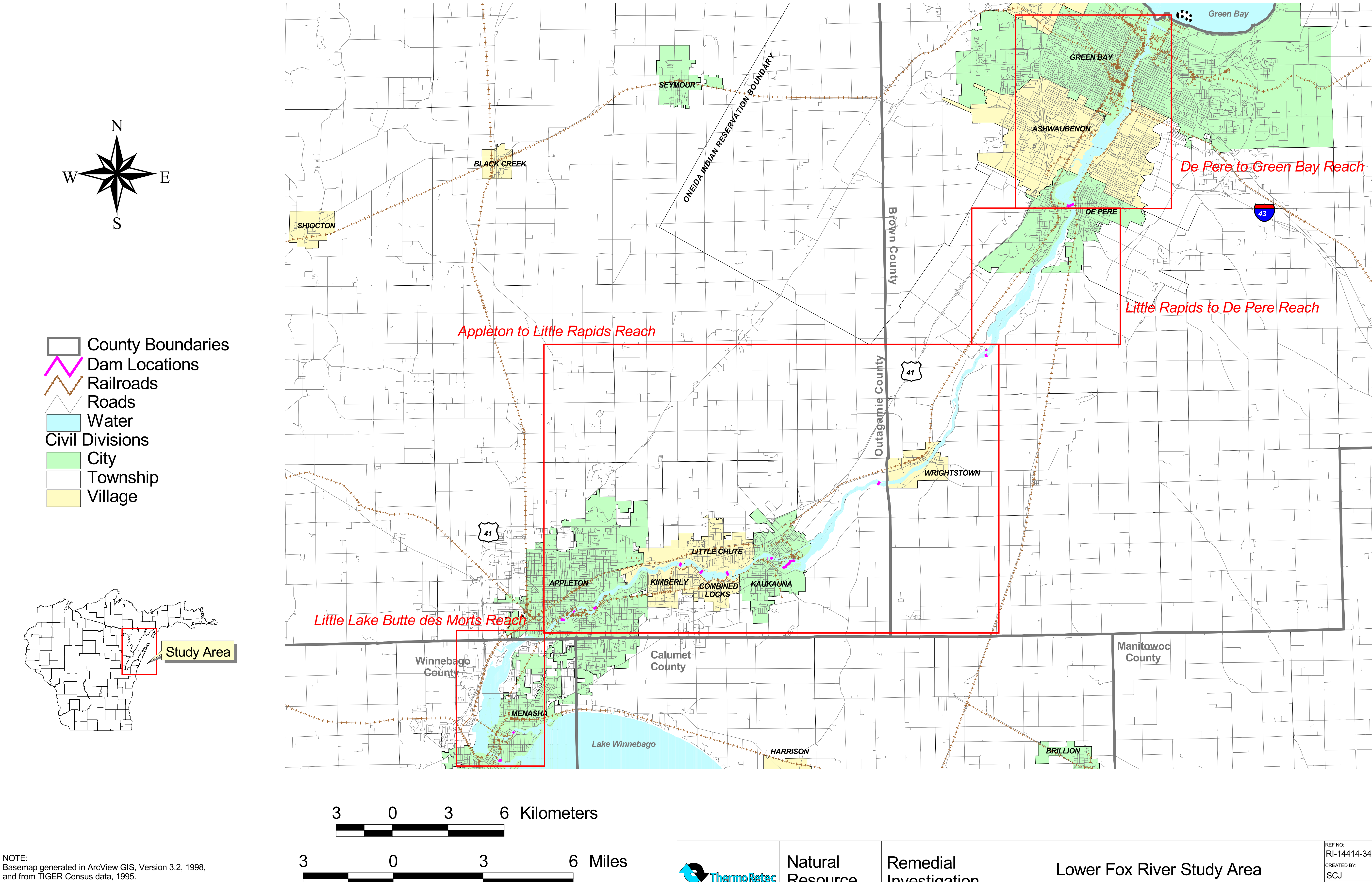
- Using an extensive body of site-specific scientific information and data to bound the problem, and by calibrating and defining the uncertainty of models that were used in the risk assessment and feasibility study.

- There are no presumptive remedies. All potential remedial alternatives (including natural attenuation) are evaluated using a range of risk-based sediment clean up values. Local site conditions, feasibility, and estimated long-term risk reduction were defined and estimated for several remedial alternatives (dredging, capping, natural recovery) and carried forward in the FS. Selection of a final remedy will be a management decision defined in the Remedial Action Plan and Record of Decision (ROD),

EPA's 11 risk management principles also are covered by the above bullet, as well as through public involvement, development of sophisticated fate, transport, and bioaccumulation models, early involvement of trustee groups, and implementation of three demonstration projects to test potential remedial technologies.

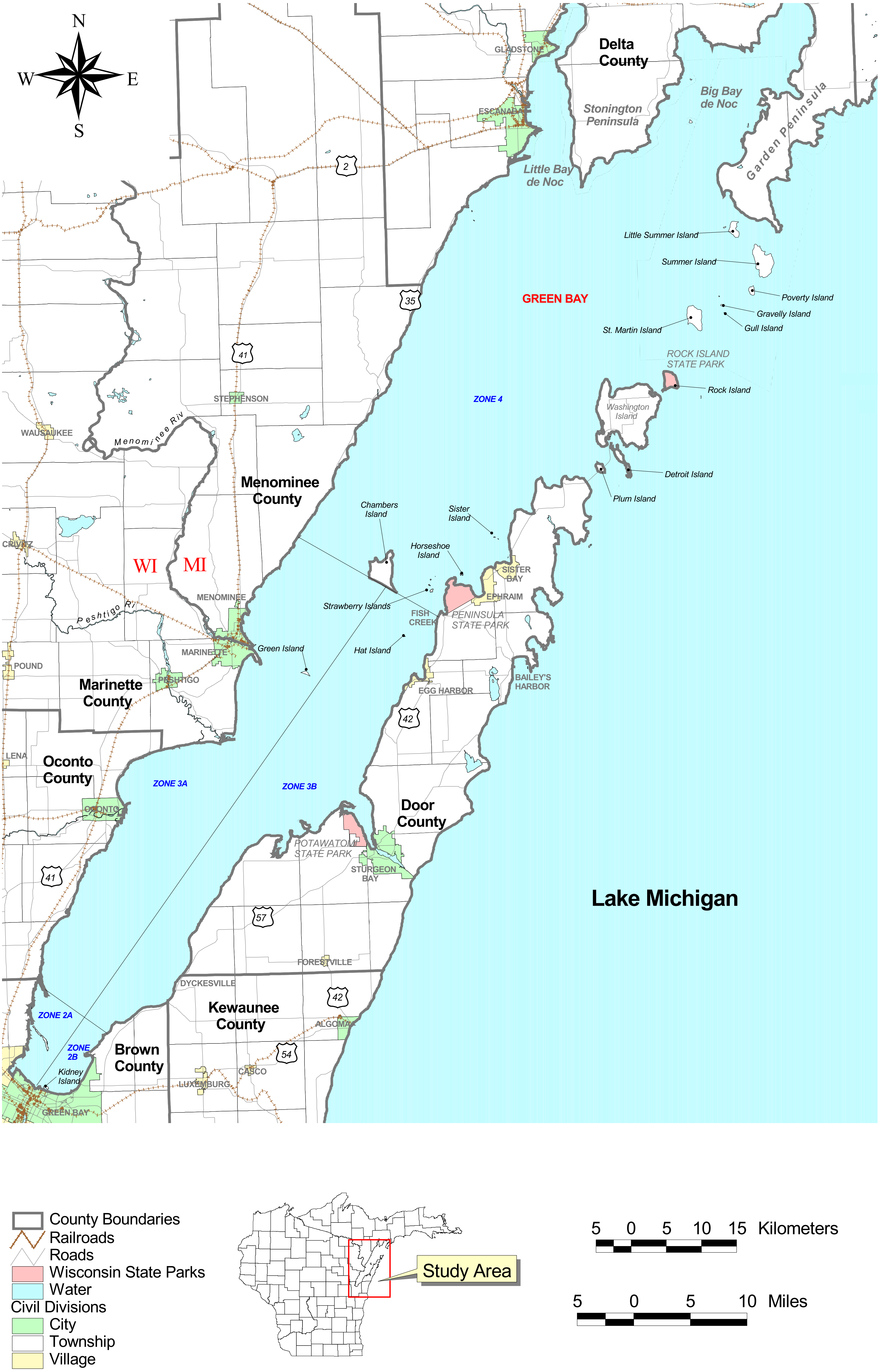
1.6 Section 1 Figures

Figures for Section 1 follow this page, and include:



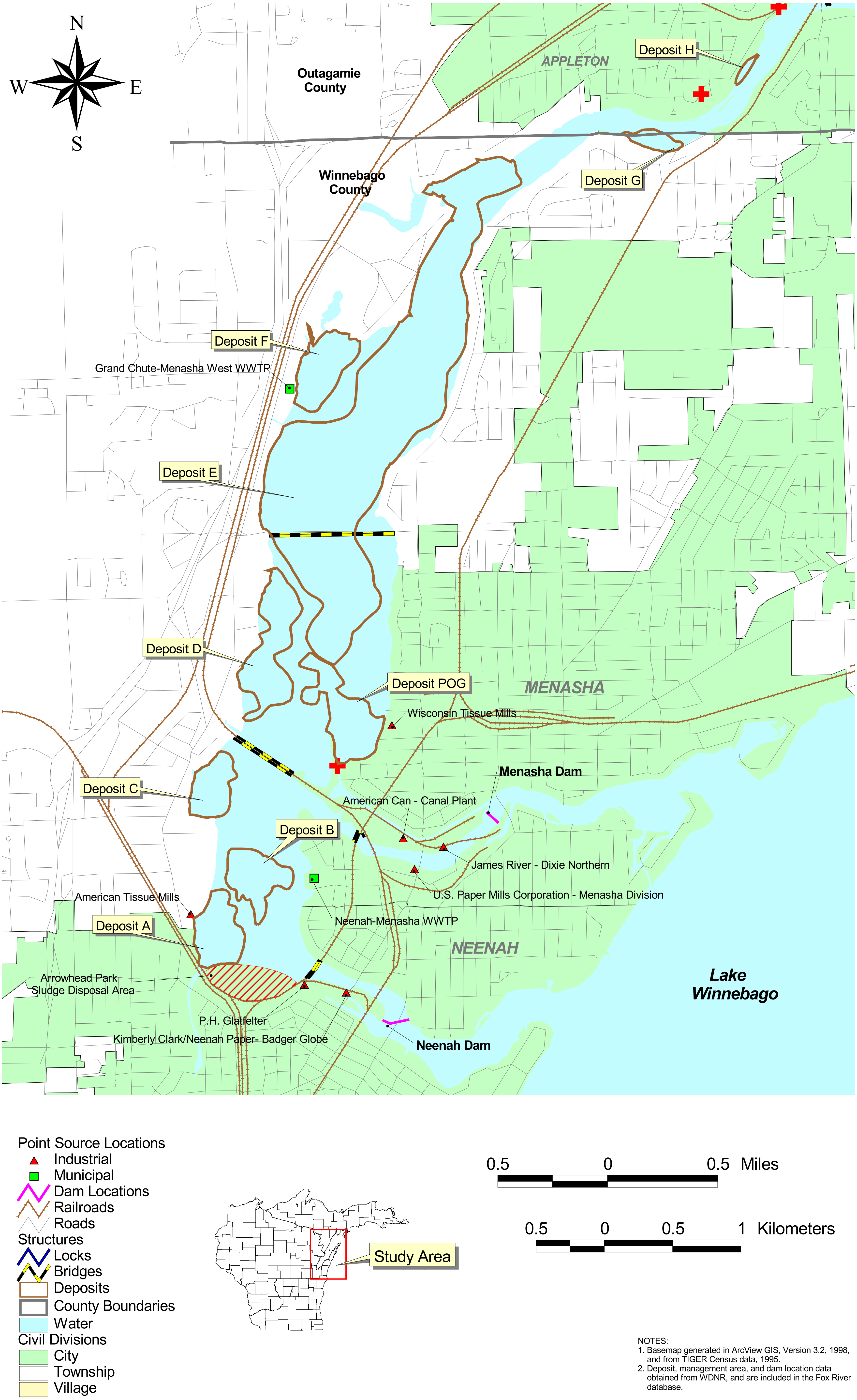
NOTE:
Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Lower Fox River Study Area	REF NO: RI-14414-340-1-1 CREATED BY: SCJ PRINT DATE: 3/14/01 APPROVED: AGF
			FIGURE 1-1	



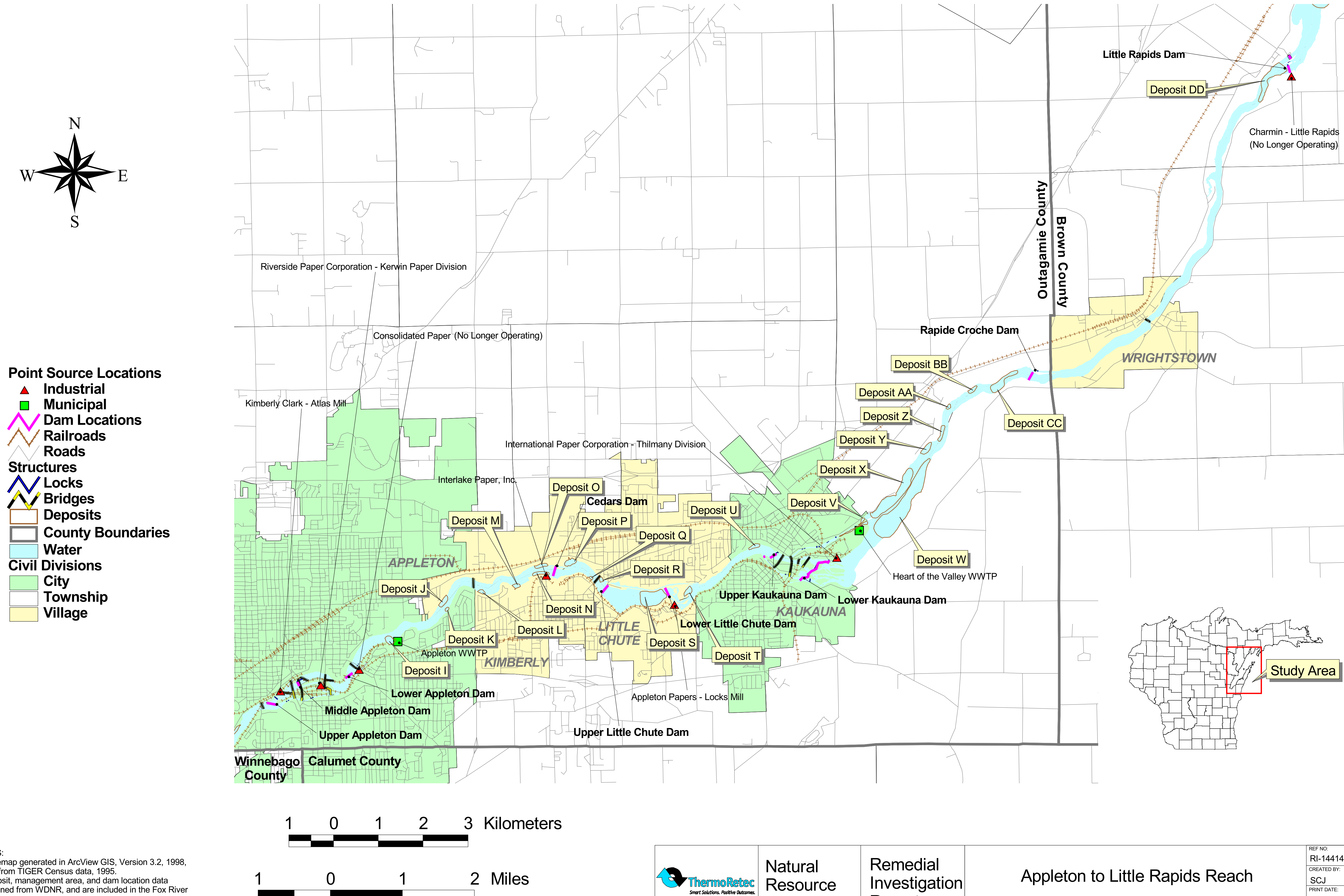
NOTE:
Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Green Bay Study Area	REF NO: RI-14414-340-1-2
				CREATED BY: SCJ
				PRINT DATE: 3/14/01
			FIGURE 1-2	APPROVED: AGF



NOTES:
1. Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.
2. Deposit, management area, and dam location data obtained from WDNR, and are included in the Fox River database.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Little Lake Butte des Morts Reach	REF NO: RI-14414-340-1-3 CREATED BY: SCJ PRINT DATE: 3/7/01 APPROVED: AGF
			FIGURE 1-3	



NOTES:
1. Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.
2. Deposit, management area, and dam location data obtained from WDNR, and are included in the Fox River database.

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Natural Resource Technology

Remedial Investigation Report

Appleton to Little Rapids Reach

FIGURE 1-4

REF NO: RI-14414-340-1-4
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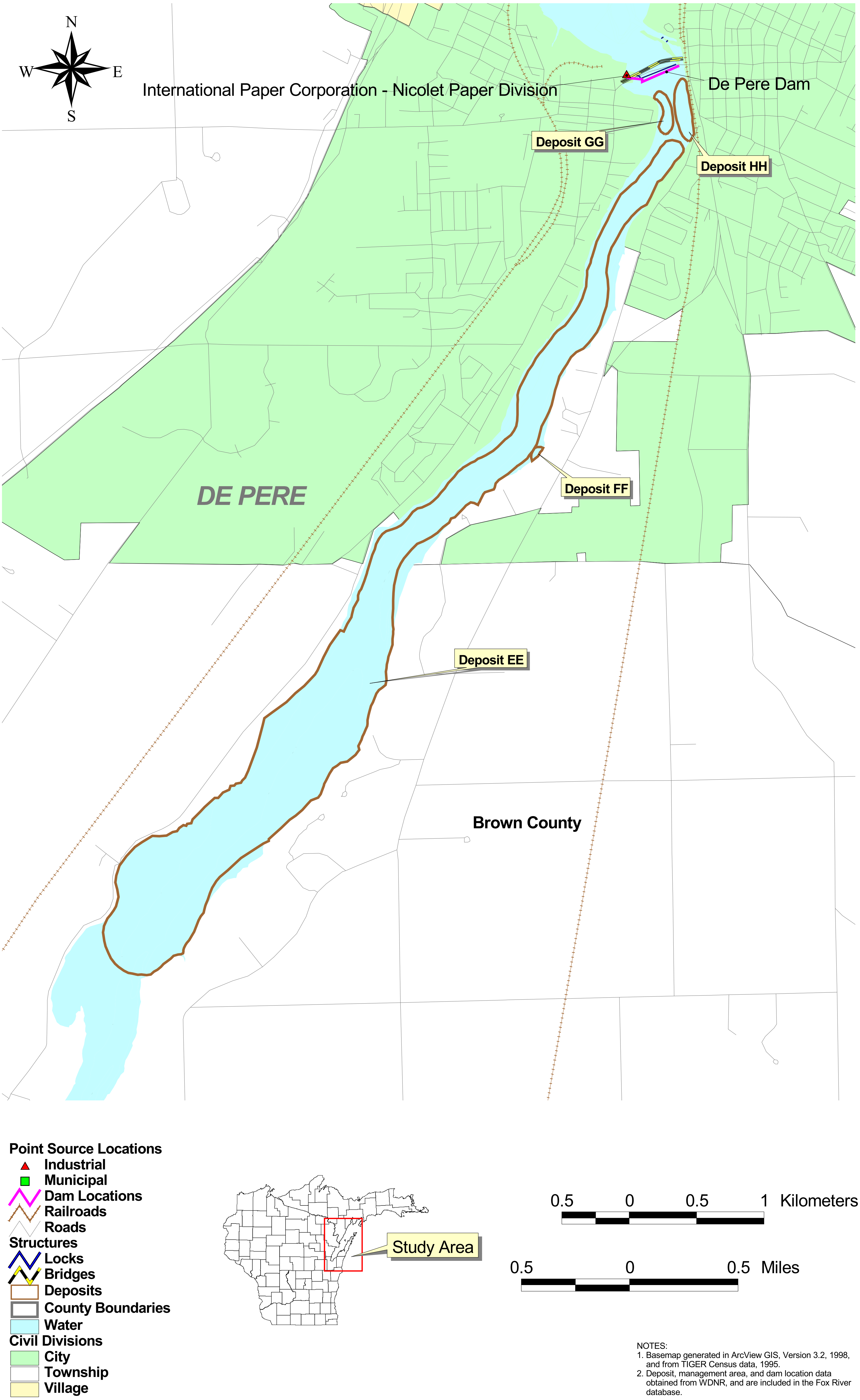
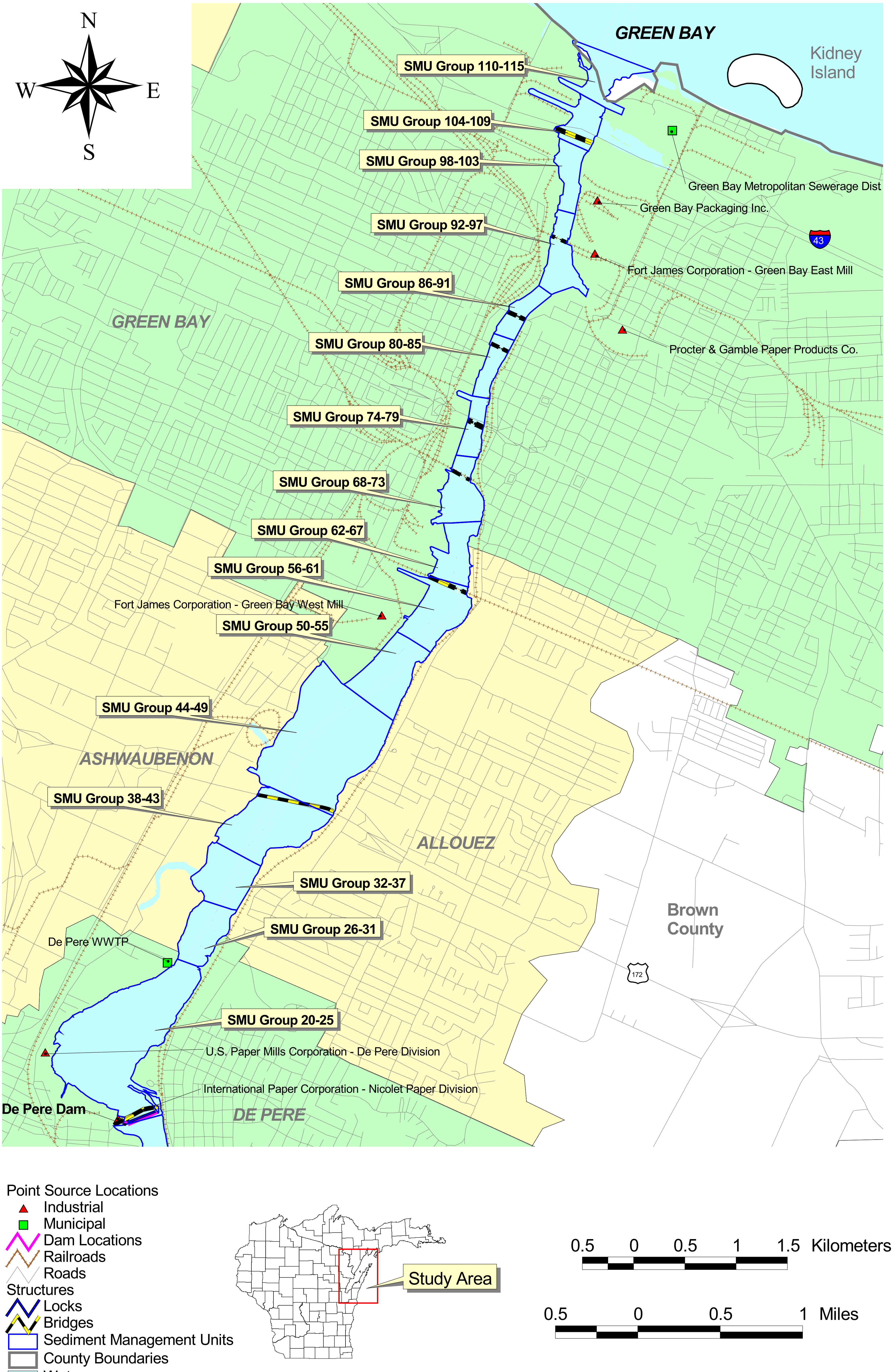


ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Little Rapids to De Pere Reach	REF NO: RI-14414-340-1-5 CREATED BY: SCJ PRINT DATE: 3/7/01 APPROVED: AGF
			FIGURE 1-5	



NOTES:
1. Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.
2. Deposit, management area, and dam location data obtained from WDNR, and are included in the Fox River database.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	De Pere to Green Bay Reach	REF NO: RI-14414-340-1-6
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 1-6	APPROVED: AGF